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DRYING POTATOES FOR FEED IN A DIRECT-FIRED, ROTARY DRIER. ECONOMIC FEASIBILITY OF THE PROCESS[1, 2]

PAUL W. EDWARDS, A. HOERSCH, JR., C. S. REDFIELD AND RODERICK K. ESKEW

This paper describes a method of converting white potatoes to stable form in which they may be conveniently stored, shipped and used for feed or as raw material for industrial fermentations.

The Bureau of Agricultural and Industrial Chemistry Circular AIC-209, "Producing Feed and Flour from White Potatoes with Steam Tube Driers," describes a method developed at the Eastern Regional Research Laboratory by which idle equipment in distilleries or other plants can be used. That process requires steam, which usually is not available at potato storage plants in sufficient quantities to operate steam tube driers.

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[2]Eastern Regional Research Laboratory, Philadelphia 18, Pa.
One of the Laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriclluture.

The method described in this paper uses a direct-fired, rotary drier. These driers are simple to operate and are widely used for drying farm crops and require no source of steam. In the northern states where potato storage facilities are available, potatoes could be dried from October 1 through May and forage crops or vegetable wastes (1) could be dried during the summer. This permits the use of the plant throughout a large part of the year and thus reduces the cost of making the products.

General Description of Process

The process consists essentially of the following steps: (1) Wash the potatoes; (2) grind them in a hammer mill; (3) continually mix the ground potatoes with some of the dried product; (4) dry the mixture in a direct-fired rotary drier; (5) screen the dried potato to remove the fines before recycling to the mixer; (6) then bag the remainder of the coarse material and all the fines as product.

Equipment Requirements and Details of the Process

It is assumed that the potatoes have an average moisture content of 80 per cent. It is also assumed that the potatoes will be delivered to the factory from an adjacent storage plant by means of an underground or totally enclosed screw conveyor; hence, no storage facilities are provided.

The equipment is that required for a factory processing 62 tons of potatoes in 24 hours and producing 13.8 tons of feed containing 10 per cent moisture.

Washing: The potatoes are conveyed to the washer by a 9-inch screw conveyor equipped with a speed controller. A washer (3) such as that ordinarily employed in potato starch factories is well suited for this purpose. This consists of a U-shaped trough divided into sections and equipped with rotating paddles, which keep the potatoes in rapid motion and lift them from one compartment to the next, while water flows continually through the washer. The stones and much of the dirt settle to the bottom of the trough and are periodically removed by flushing. Stones must be removed to prevent damaging the hammer mill and pumps. A trough approximately 2½ feet in diameter and 25 feet long with four compartments will wash 62 tons of potatoes in 24 hours thoroughly.

Grinding: To reduce the potatoes to a form suitable for drying, they are ground in a hammer mill equipped with a screen having holes ⅜ inch in diameter. Ordinary blunt hammers may be used. One mill 6 inches wide by 12 inches in diameter driven with a 7½ horsepower motor should have sufficient capacity. The speed of the mill should be sufficient to give a hammer tip speed of approximately 6500 feet per minute. Much higher tip speeds may require a coarser screen to avoid too fine a product.

The ground potatoes are discharged into a 300-gallon wooden tank equipped with a slow-moving, paddle-type agitator, which prevents the solids from settling. This tank holds sufficient ground potatoes to operate the drier for nearly one-half hour and serves as a reservoir in case repairs must be made to the washer or hammer mill.

Mixing: To prevent the material from sticking to the drier or forming balls that cannot be satisfactorily dried, the moisture must be reduced to

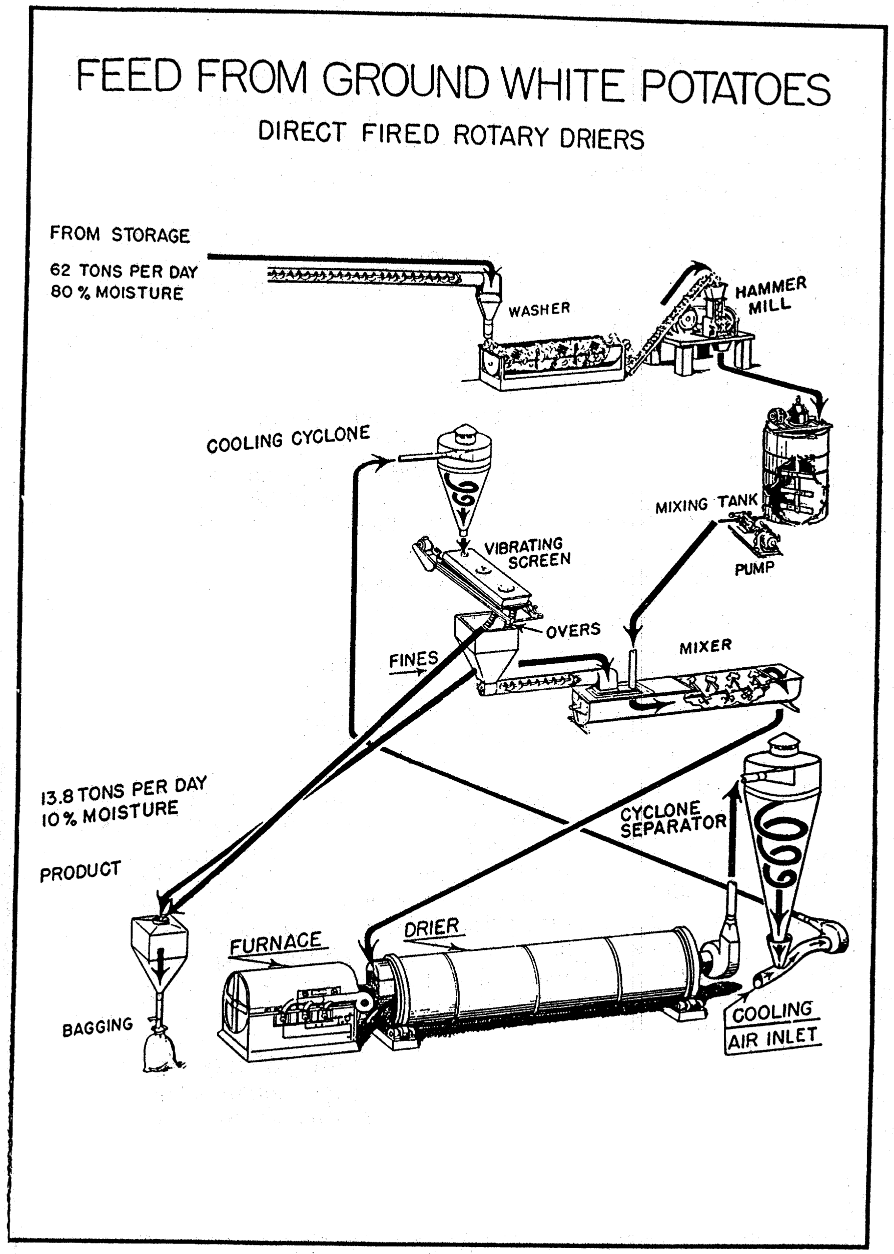

Fig. 1.—Diagrammatic sketch of equipment layout

approximately 42 per cent. This is accomplished by continuously recycling a sufficient quantity of the dried product and mixing it with the ground potatoes. Experience has shown that this cannot be satisfactorily accomplished, even with good mixing, in less than 4 minutes; a period of 6 or 7 minutes is preferable. With proper mixing and a sufficiently long retention time to permit the dried material to rehydrate, the mixed product when squeezed in the hand will form a ball that crumbles easily, and if dropped from a height of only 3 feet will break into small pieces. For the proposed factory a paddle-type mixer-conveyor 20 inches in diameter and 50 feet long is required. To conserve floor space, this mixer may be made in two sections, 20 and 30 feet long, respectively, with one section located above the other. A 10-horsepower motor is required to drive the mixer. The mixer-conveyor must be equipped with adjustable paddles so that a retention time of 6 to 7 minutes can be obtained. A variable-speed, positive-delivery pump of a type that will not further disintegrate the potatoes is required to convey the ground potatoes, and a screw conveyor with a speed controller is required for metering the dried product to the mixer-conveyor. These permit close control of the wet stock fed to the drier.

With potatoes and products containing 80 and 10 per cent moisture, respectively, the pump must deliver 5160 pounds of ground potatoes and the metering conveyor 6130 pounds of dry product each hour to the mixer-conveyor.

Drying: The drier used in our investigations was a small, commercial-size, multipass, oil-fired rotary drier, of the type commonly used to dry alfalfa. The rotating body, 16 feet long, is made up of three concentric cylinders, 2½, 5 and 7 feet in diameter, respectively. The inner cylinder is the combustion chamber. The oil burner is mounted at one end of this cylinder, and protrudes from the main body. The drying air, drawn in by an exhaust fan through openings adjacent to the burner, is heated by mixing with the products of combustion.

The material from the mixer-conveyor is carried to the top of the drier, where it falls into the screw feeder, which carries it into the drier. Here it meets the heated air and products of combustion and is carried by them through the annular spaces of the drier to an exhaust fan. The gases and dried product from this fan are delivered to a cyclone separator adjacent to the drier. The hot gases escape through the top of the separator, and the dried material falls through the bottom. Here a stream of cold air from another fan picks up the dried material and conveys it to a cooling cyclone separator. From the bottom of the second separator, the dried material falls into a vibrating screener.

Tests made with this drier, with an inlet gas temperature of 1200°F., produced a product that was not scorched and had a good potato odor. During this test, the feed rate used gave an exit gas temperature of approximately 210°F., and the product contained less than 10 per cent moisture. An inlet gas temperature of 1200° was about as high as could be obtained with our drier. It is possible that this material might be dried at higher inlet gas temperatures without scorching, and thus increase the capacity of the plant and reduce the cost of making.

Drying tests made in our drier gave over-all thermal efficiencies of nearly 80 per cent, which is good for a drier of this type.

Calculations based on our experience with the 7 x 16 feet multipass rotary drier show that a triple-pass rotary drier 8 x 24 feet will evaporate 4010 pounds of water per hour from potatoes prepared in the manner described, with an inlet gas temperature of 1200°F. A drier having this evaporative rate will dry 62 tons of potatoes having 80 per cent moisture to 13.8 tons of product at 10 per cent moisture in 24 hours. Presumably other properly designed driers of the rotary type, single or multiple-pass, could be employed.

The fans and cyclone separators in this drier must handle 7280 pounds per hour of dried material, weighing about 43 pounds per cubic foot, because of the recycling technique. The fan for the cooling system normally furnished on rotary alfalfa-type driers may not be large enough to convey this amount of dried material. The cooling fan on our drier did not have sufficient capacity to handle all the dried potatoes when the drier was operated at 1200°F. For these reasons, the drier manufacturer should be consulted regarding both fan and cyclone separator requirements for the cooling system. To prevent the production of a large amount of fines, and to reduce the possibility of dust explosions and fires initiated by foreign material striking the fan, it is recommended that the material be sucked rather than blown through the system. This can be accomplished by connecting both the hot and cold cyclone separator fans to the gas discharge side of the cyclone separators, which will require the use of air locks on the bottom of both cyclone separators.

Screening: The 100-mesh fines must be removed from the dried material which is recycled in order to reduce the possibility of having a dust explosion or fire. This is accomplished by removing all the 100-mesh fines from the dried material as it comes from the cooling cyclone separator. For the 62-ton plant, a vibrating screener equipped with a 100-mesh screen approximately 3½ feet wide and 8 feet long supported by a coarse backing screen should have sufficient capacity to handle 7280 pounds per hour of dried material.

The coarse material which goes over the screen falls into a hopper. Part of it is recycled by a metering conveyor to the mixer-conveyor. The remainder passes to the bagging bin, where it is combined with the fines from the screener and then is bagged as product and stored.

Costs

To have definite figures on all items entering into the cost calculations, a specific area for the plant was chosen. Aroostook County, Maine, was selected because of the large quantities of potatoes grown there and because of the shortage of feeds produced in that area. It is also reported that dairy cattle and poultry are being raised there in increasing numbers.

The following assumptions are made. The factory will be operated in conjunction with existing potato storage operations. Therefore, no charge for land, roads or railroad siding is included in the capital costs. Furthermore, no fees for storage of the raw potatoes are included in the costs. The building proposed is of wood construction. The plant will dry potatoes 24 hours a day, 6 days a week, from October 1 to May 31. Parts of the plant will operate from June 15 to August 31, drying clover or other forage crops. The factory will operate 210 working days on potatoes and 66 working days on clover. This is a total of 276 working days per year. Such a plant located in an area where vegetables are grown commercially could be used in summer for drying vegetable wastes.

The factory will produce 13.8 tons of potato feed containing 10 per cent moisture per 24-hour day. This production will require 62 tons of potatoes. On a yearly basis this plant can produce 2898 tons of feed from 12,999 tons of potatoes. The capital costs for this plant are shown in table 1, and costs to make potato feed are given in table 2.

TABLE 1.—*Capital costs*

Site preparation	$ 525
Building, wood frame construction, 50 x 65 ft. and 15 ft. high	25,350
Boiler, heating	530
Equipment, manufacturing	
Conveyor, screw, metering	2,700
Washer	1,030
Conveyor, flight	705
Hammer mill	835
Tank, wood and agitator	690
Pump, positive delivery	485
Conveyor, metering	655
Mixer-conveyor	3,840
Drier	18,325
Vibrating screen	1,730
Collecting hopper	260
Bagging head	130
Trucks, scales and small tools	265
Erection of equipment, manufacturing	7,910
Piping and ductwork	215
Erection of piping and ductwork	170
Heating installed	1,220
Light installed	725
Power installed	2,860
Freight on equipment	630
Office furniture and fixtures	515
Contingencies	9,265
Engineering fees	11,120
Total fixed capital	92,685
Working capital	18,540
Total Capital	$111,225

When cull potatoes are available at the plant for 25 cents per hundredweight, the cost to make a ton of product would be $52.59.

No general cost estimate of this type will exactly fit the conditions of any prospective manufacturer. With an understanding of the assumptions upon which the estimate is based, however, a manufacturer should be able to make a reasonable estimate of his own costs.

It should be emphasized that the capital costs given here and the

TABLE 2.—*Daily cost to make potato feed.*

Prime cost		
Raw materials	Nil	
Labor	$108.00	
Total		108.00
Indirect materials		
Bags	66.24	66.24
Factory overhead		
Indirect Labor		
Supervision	26.84	
Watchmen	1.88	
Office help	8.48	
Truck operator	10.00	
Total indirect labor		47.20
Indirect expense		
Insurance	1.68	
Taxes	6.72	
Interest, fixed capital	16.79	
Social security	2.16	
Workmen's compensation	1.60	
Unemployment insurance	4.66	
Depreciation	23.34	
Maintenance, repairs and renewals	20.15	
Vacation time	1.30	
Power	20.47	
Steam	.92	
Oil, fuel	50.16	
Water	7.75	
Gasoline	6.00	
Factory supplies	1.15	
Total indirect expense		164.85
Total factory cost		386.29
Interest on working capital	2.76	2.76
Administrative and general expense	26.25	26.25
Total cost to make		415.30
Production rate, tons per day	13.8	
Cost to make, dollars per ton	30.09	

cost per ton for producing the products are based on the use of a new building and the purchase and installation of new equipment.

Economic Feasibility of the Process

It is of prime importance to know whether that factory, when operated 8 months on potatoes and 2½ months on clover or other materials, can make a reasonable profit. This should depend on the feed value of dried potatoes as compared with corn, and will depend upon the price paid for cull potatoes. The following is an analysis of potato feed made at the Eastern Regional Research Laboratory by the process described.

	Per cent
Moisture	6.90
Protein (N x 6.25)	11.64
Fiber	2.41
Fat	.12
Ash	5.32
Carbohydrate (by difference)	73.61

Information compiled by Allender (2) on the feeding of dairy and beef cattle, lambs and swine showed that when dried potatoes were used as part of the rations to replace part and, in some instances, all the corn or other grains in the rations, the animals responded satisfactorily. In one experiment with lambs, one lot was fed dried cubed potatoes, which constituted the only concentrate in the ration. As compared with whole corn, the dried cubed potatoes fed alone produced 7 pounds more gain per lamb during the 84-day feeding period, and consumption of the cubed potatoes and alfalfa hay was lower per 100 pounds of gain, in comparison with the lot receiving corn. In this test, based on only one lot of lamb for 1 year, the cubed potatoes proved to be worth one-third more than whole corn.

Feeding tests (4) have shown that there was no effect on the live weight or the dressed weight of White Pekin ducks, marketed at 9 weeks of age, when 20 per cent of potato meal was substituted for 20 per cent of corn meal, 20 per cent of wheat standard middlings, or 10 per cent of corn meal plus 10 per cent of wheat standard middlings. Therefore, in 100 pounds of control ration containing 30 pounds of yellow cornmeal and 25.0 pounds of wheat standard middlings, 20 pounds of dried potato feed could be substituted for 20 pounds of corn meal, 20 pounds of wheat standard middlings, or 10 pounds of corn meal plus 10 pounds of wheat standard middlings. Thirty per cent of potato meal is probably the maximum amount that could be fed under these conditions, since there was some indication in one trial that when 30 per cent of potato meal replaced 15 per cent of corn meal plus 15 per cent of wheat standard middlings, the weight was slightly reduced. In these tests, there seemed to be no difference between the potato feed prepared at the Eastern Regional Research Laboratory and air-strip dried potato meal.

These data indicate that dried potatoes, corn, and corn meal are almost equal in value for the feeding of livestock.

Based on the assumption that dried ground potatoes are equal to corn as feed, table 3 gives the manufacturer's profit on the fixed investment ($92,685) after deductions for sales expense and income tax, when cull potatoes are available at 25 cents per hundredweight.

Table 4 shows the price that the manufacturer can pay for cull potatoes and realize 15 per cent net profit on fixed investment after payment of sales expense and income tax.

From table 3 it is apparent that corn must sell at $2.00 a bushel to enable a potato feed manufacturer to make a reasonable profit, 14 per cent, on his fixed investment. This presupposes that he must pay 25 cents per hundredweight for cull potatoes delivered to the plant. If corn should sell for $3.00 a bushel, his profit would be 53 per cent.

TABLE 3.

When Corn Sells at	Corn or Potato Feed is Worth	Profit Based on Fixed Investment*
$/Bus.	$/Ton	Per cent
1.75	62.48	4.1
2.00	71.40	14.0
2.25	80.33	23.9
2.50	89.25	33.7
2.75	98.18	43.6
3.00	107.10	53.4

* When cull potatoes are available at 25 cents per cwt.

TABLE 4.

When Corn Sells at	Corn or Potato Feed is Worth	Manufacturer Can Pay for Cull Potatoes*	
$/Bu.	$/Ton	$/Ton	$/Cwt.
1.50	53.55	1.11	.056
1.75	62.48	2.96	.148
2.00	71.40	4.81	.241
2.25	80.33	6.66	.333
2.50	89.25	8.51	.426
2.75	98.18	10.36	.518
3.00	107.10	12.21	.611

*Based on 15 per cent profit on fixed investment after payment of sales expense and income tax.

If the manufacture of potato feed is an enterprise owned by potato growers, they could sell cull potatoes for prices shown in table 4, corresponding to the current corn price, and also obtain 15 per cent return on the factory fixed investment. For example, an increase in the price of corn from $2.00 to $3.00 a bushel would increase the value of culls from 24 cents to 61 cents a hundredweight.

It should be emphasized that the data shown in tables 1, 2, 3 and 4 are based on a factory that will make potato feed 24 hours a day, 6 days a week, for 8 months each year from potatoes having a moisture content of 80 per cent. It will also dry other materials during 2½ months each year. It is assumed in tables 3 and 4 that potato feed is equal to corn in feeding value.

Usually, it is difficult to sell a new feedstuff at a price justified by its feeding value. Potato feed is a good example of this. It has been established by large-scale duck feeding experiments (4) that potato feed can be substituted for corn meal to approximately 20 per cent of the ration. The average price paid by New York State farmers June 15, 1951, for corn meal (5) was $4.25 per hundredweight, or $85 per ton. Obviously, potato feed should have been of equal value for feeding ducks. However, a recent survey made on Long Island, New York, where both potatoes and ducks are plentiful, showed that potato feed could not be sold for that price. It was reported that a large feed mixing plant paid only $40 per ton for air-dried potato slices. This material, when ground, is equal to corn meal for feeding ducks (4). It is obvious that in addition to technical "know how," a good merchandising program is required to make the artificial drying of potatoes for feed profitable.

In many potato growing areas, it is not feasible to store potatoes for 8 months. In order to make potato feed profitably in these areas, by the method described, potatoes could be dried in available direct-fired, rotary driers used chiefly for some other purpose. For example, a drier used in the summer for drying alfalfa, could be used with auxiliary equipment for drying ground potatoes after the alfalfa season. By distributing some of the costs over a longer operating period, it is reasonable to expect that both the cost of drying alfalfa and the cost of making potato feed would be reduced considerably.

Summary

A practical method has been developed for making potato feed with a direct-fired, rotary, alfalfa-type drier.

A plant processing 62 tons of potatoes daily would produce about 13.8 tons of feed, at a cost of about $30.09 per ton. This plant would cost about $92,500. If cull potatoes are available at 25 cents per hundredweight, the cost to make a ton of product would be about $52.59. Based on the assumption that dried potatoes are equal to corn in feeding value, if corn sells at $2.25 per bushel, a Maine potato feed manufacturer might realize a profit of approximately 24 per cent on his fixed investment after payment of sales expense and income tax. These estimates are based on 8 months' operation on potatoes and 2½ months on drying other crops or vegetable field wastes.

Since potato feed is a relatively new commodity, a good sales promotion program will be required to enable it to compete with corn.

Potato feed should be made more profitably in areas where there are established drying plants, *i.e.,* alfalfa dehydrators, by operating in conjunction with them.

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